

# ICESat-2: Exploring the Nature of the Earth's Changing Ice Cover

Waleed Abdalati – Science Definition Team Lead, Earth Science and Observation Center, CIRES, University of Colorado at Boulder,  
Thorsten Markus – Project Scientist, Tom Neumann – Deputy Project Scientist, Douglas McLennan - Project Manager, NASA Goddard Space Flight Center  
David Hancock and John DiMarzio – Data System Managers, Sigma Space and SGT, Inc at NASA Goddard Space Flight Center

The Earth's polar ice cover is one of the most sensitive components of the Earth system to climate change, and it has the potential to impact climate and sea level dramatically. The last decade has seen change occur far more rapidly than was ever thought possible.

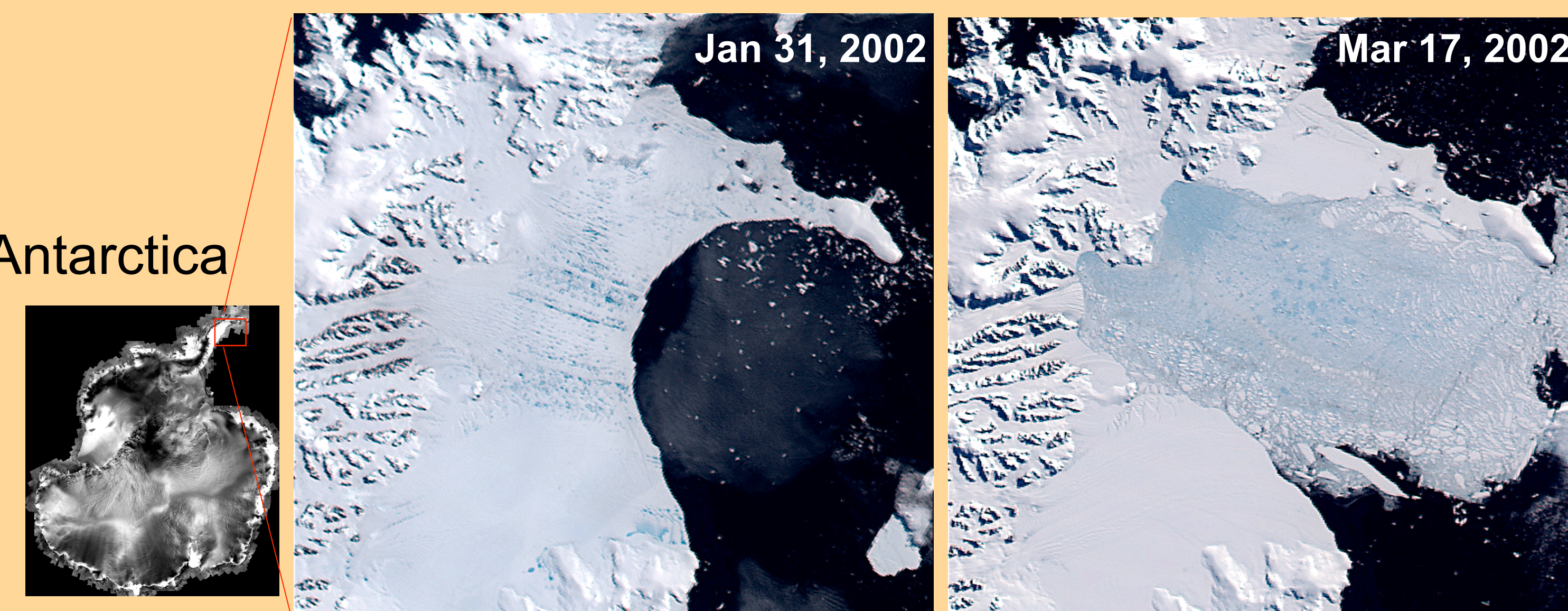
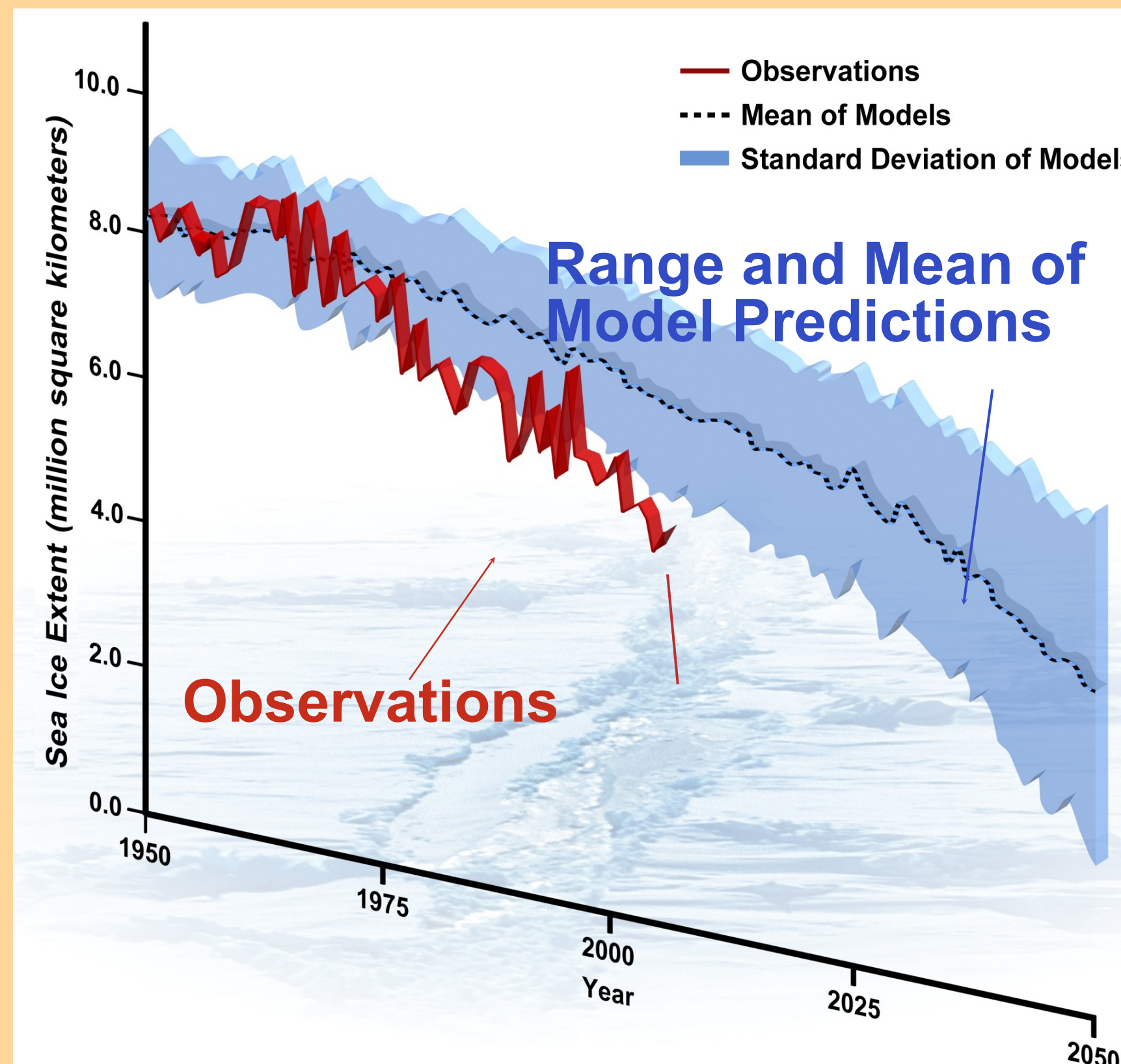


Figure 1: MODIS imagery of the Collapse of the Larsen B ice Shelf on the Antarctic Peninsula (Courtesy of T. Scambos)

The rate of sea ice decline over the last several decades is significantly greater than the range estimated by nearly all climate prediction models used in the IPCC Fourth Assessment Report. The 2007 sea ice cover was at the level predicted for 2050. The key variable missing from these model estimates is accurate ice thickness information, which is being derived for the entire Arctic and Antarctic sea ice cover from ICESat observations

Figure 2: Observed (red) and modeled (blue) decline of Arctic perennial sea ice cover (Figure courtesy of NCAR).

For example, the in 2002, the Larsen B ice shelf, believed to be more than 10,000 years old, with an area approximately the size of Rhode Island, and about 700 feet thick, disappeared in just over one month. In response the glaciers that fed the ice stream accelerated significantly, one by as much as eight-fold



Understanding the nature of these dramatic changes in polar ice requires three-dimensional observations of topography and elevation change. Ice sheet elevation change information provides a comprehensive picture of integrated effects of accumulation, surface ablation, and discharge. Such information is critical for determining the contributions of ice sheets, which hold the equivalent of nearly 70m of sea level, to sea level rise. In addition, this information provides important insights into the underlying mechanisms that drive ice sheet change. Particularly when coupled with complementary measurements, such as mass change from a GRACE follow-on mission, and outlet glacier flow characteristics from DESDynI's InSAR

In the case of sea ice, thickness information is crucial for assessing the vulnerability of the ice to rapid decay. Thickness is estimated from measurements of the height of the floating ice surface above open water leads and adjusting for buoyancy effects.

5 years of data from the current ICESat mission show that Greenland and key parts of Antarctica are thinning at their margins - very rapidly in some places -

and thickening slightly at their interior. ICESat data also show that Arctic sea ice is thinning substantially, such that the volumetric rate of loss is significantly greater than the loss in area.

ICESat has provided an important new and valuable tool for understanding the behavior of the Earth's ice cover and various other aspects of the Earth system. As a result, the NRC Decadal Survey identified its follow-on, ICESat-2, as a high-priority near-term mission. The survey recommended the earliest possible launch of a system to achieve the following objectives:

- Determine mass balance of **ice sheets and their contributions to sea level**
- Repeat measurements of **sea ice freeboard, enabling estimates of sea ice thickness change**
- Measure canopy depth to support estimating **changes in terrestrial biomass**

"Given the rapidity of the change in polar sea ice and ice sheets and the limited remaining lifetime of ICESat, a critical gap would arise if the new measurements were not made prior to ... 2015". [NRC Decadal Survey, 2007]

Ice sheet contributions to sea level, changes in sea ice thickness, and large-scale assessment of terrestrial biomass have been successfully achieved with the current ICESat mission.

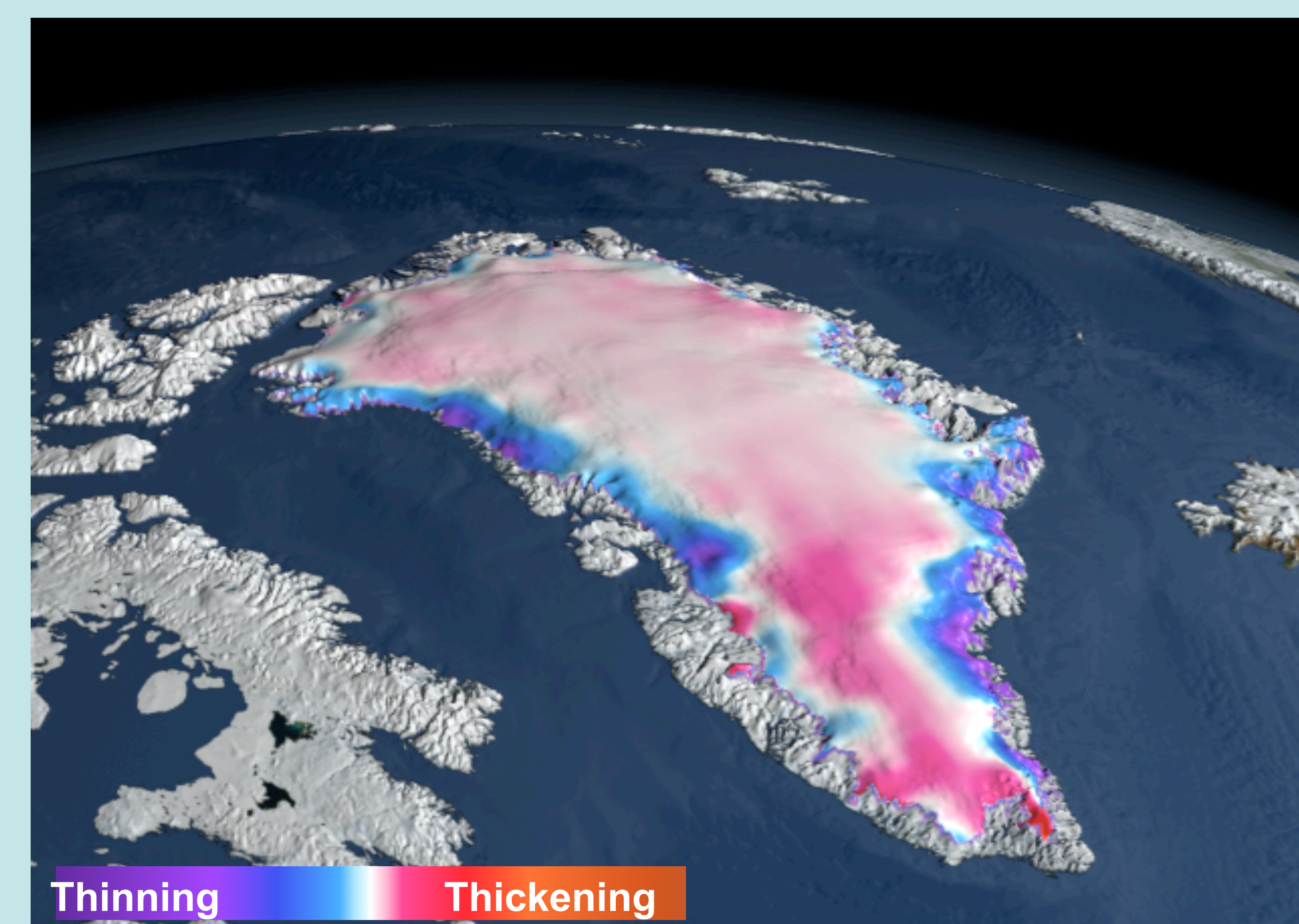


Figure 4: ICESat-derived elevation changes on the Greenland ice sheet show substantial thinning at the margins and slight thickening at the interior

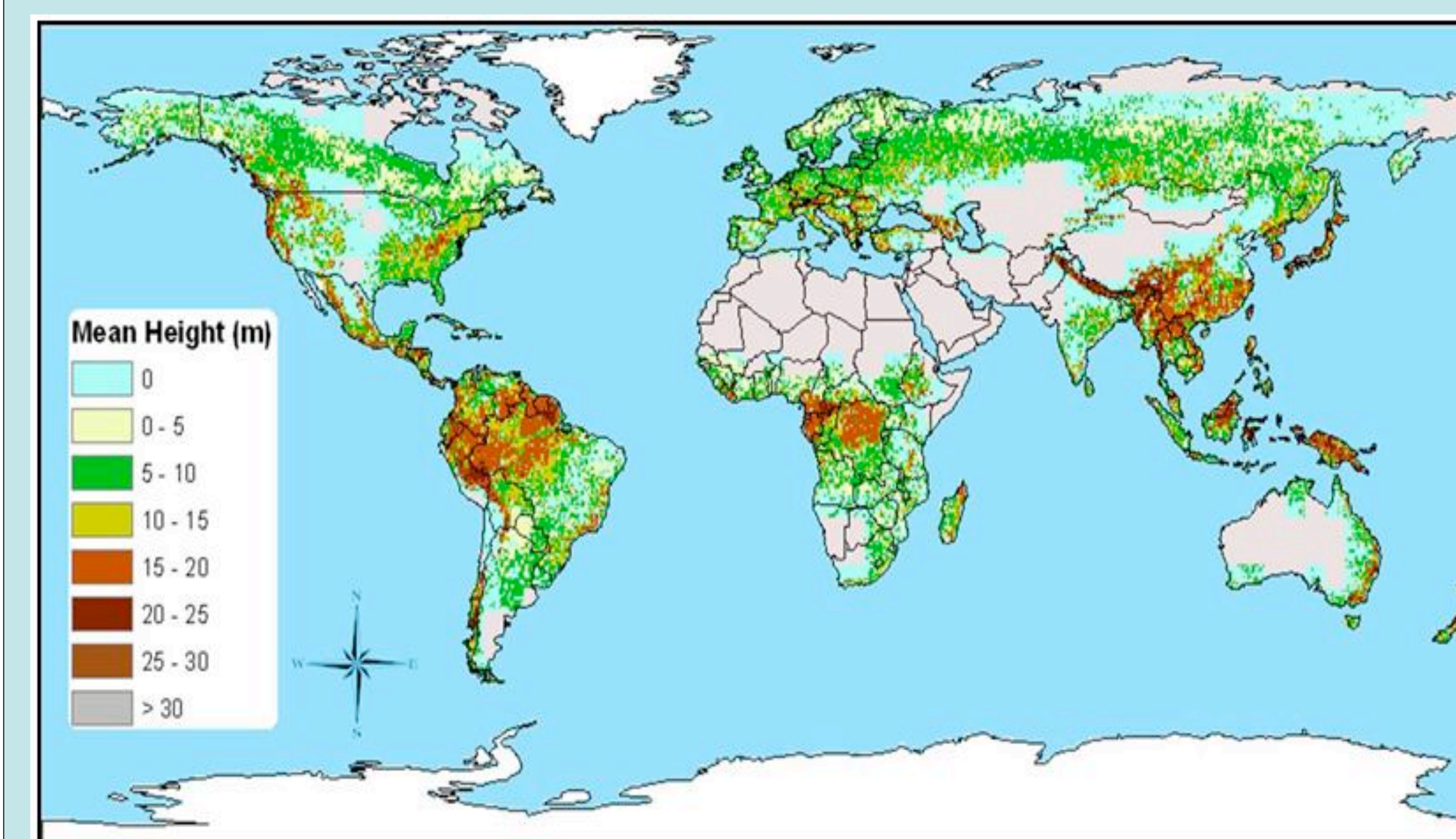


Figure 6: Global estimates of mean canopy height derived from ICESat. The capability of retrieving tree height with ICESat-2 will contribute to the large-scale biomass assessments (results provided by Mike Lefsky)

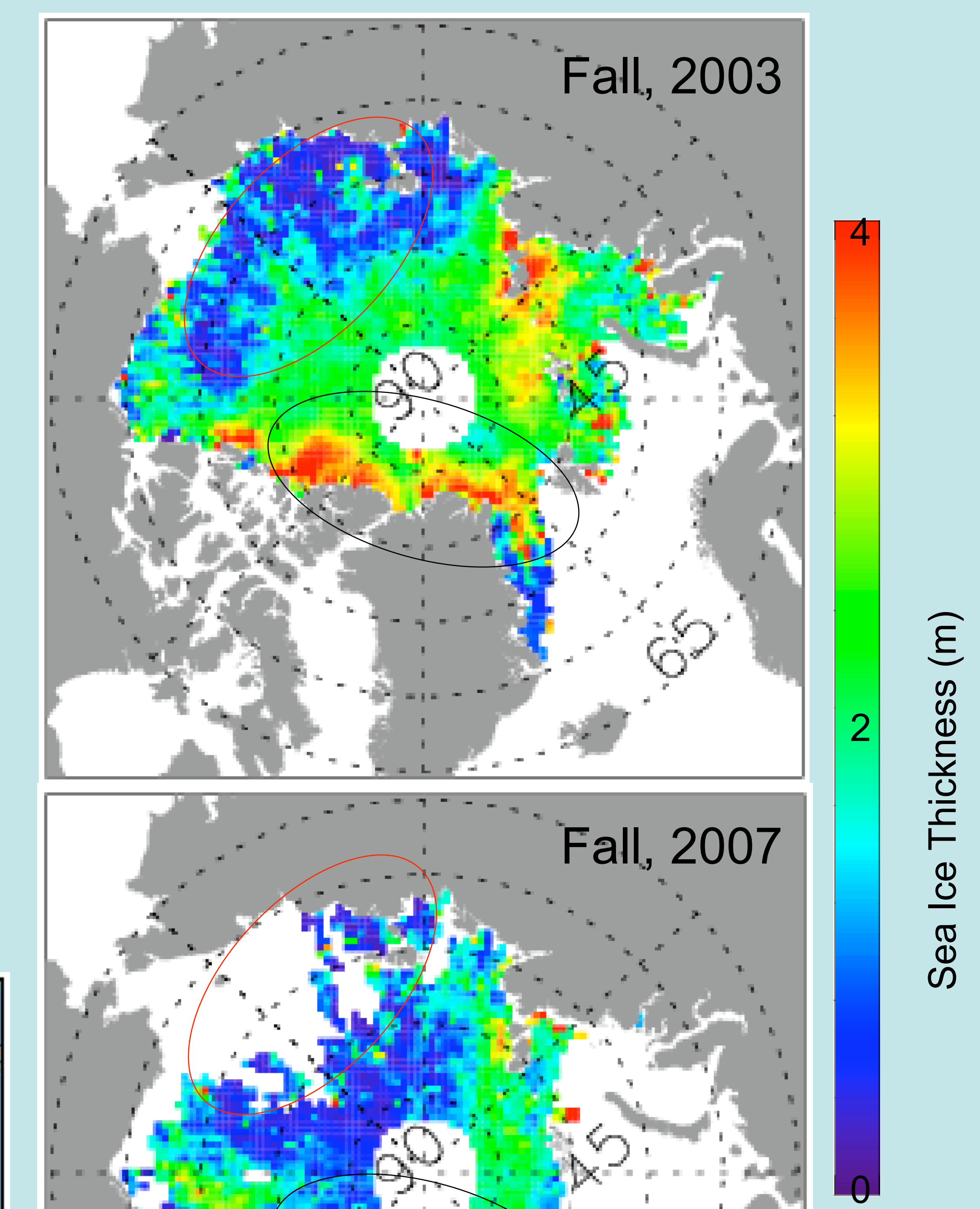


Figure 5: ICESat-derived sea ice thickness at the end of summer for 2003 and 2007. Results show the 1-2 m thick ice in 2003 thinned to 0-1 m (red ovals), and the 3-4 m thick ice has thinned to less than 2 m thick (black ovals), making the ice more vulnerable to rapid decay.

**ICESat-2 will carry the measurements initiated by ICESat into the future, and will enable trend assessments and robust model development and refinement. In so doing, it will advance the science in multiple disciplines and provide answers to some of the most fundamental questions in climate change research: How is the Earth's ice cover changing? What is driving that change, and what do these changes mean for the future?**